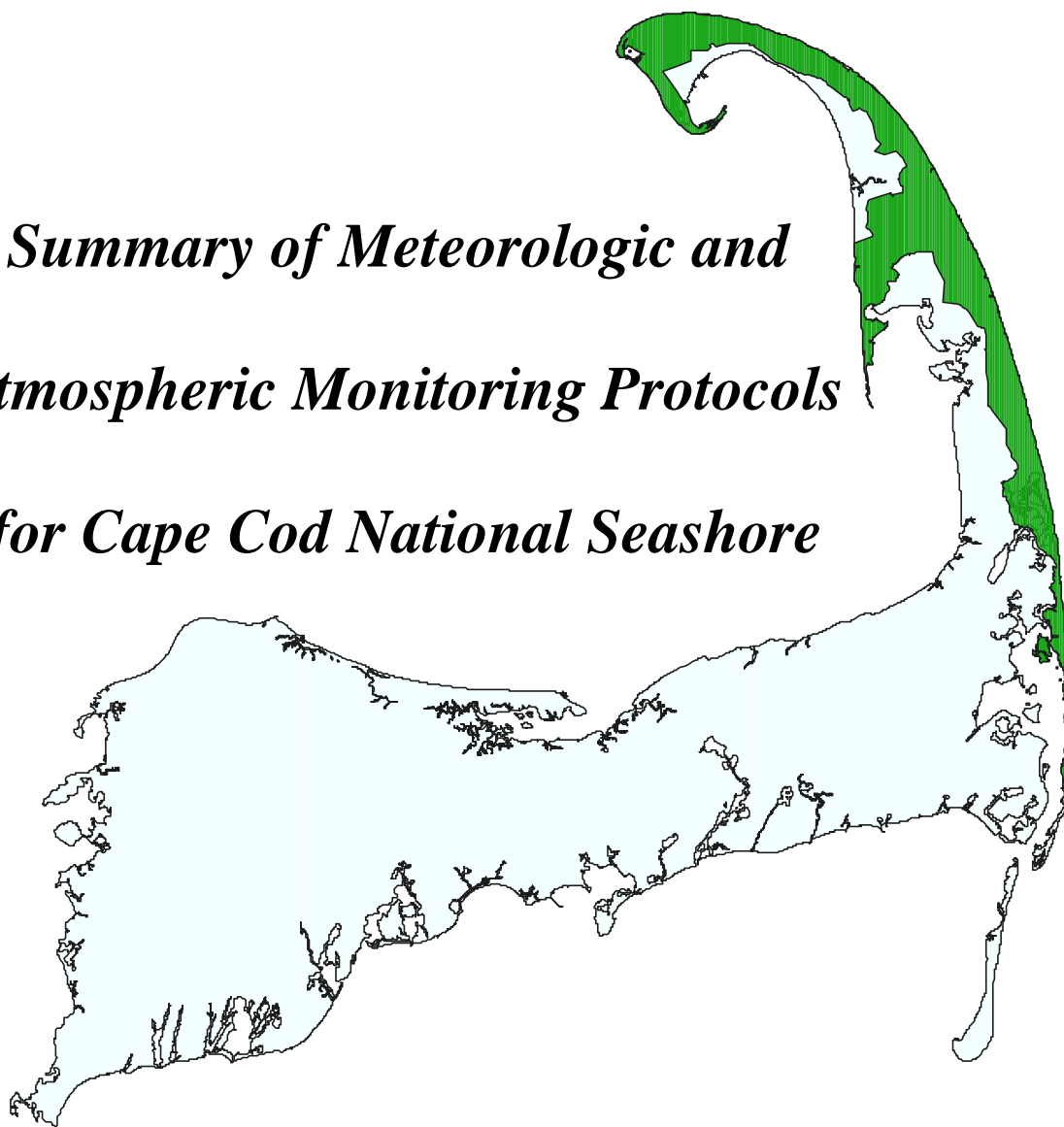




*Summary of Meteorologic and  
Atmospheric Monitoring Protocols  
for Cape Cod National Seashore*



USGS Patuxent Wildlife Research Center



Cape Cod National Seashore

# ***SUMMARY OF METEOROLOGIC AND ATMOSPHERIC MONITORING PROTOCOLS FOR CAPE COD NATIONAL SEASHORE***

A Protocol for the Long-term Coastal Ecosystem Monitoring Program  
at Cape Cod National Seashore

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Long-term Coastal Ecosystem Monitoring Program  
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*This report is on the National Park Service Inventory and Monitoring website:*  
<http://www.nature.nps.gov/im/monitor/protocoldb.cfm>



## **PREFACE**

### **Overview of Long-term Monitoring Program**

Cape Cod National Seashore serves as a National Park Service prototype monitoring park for the Atlantic and Gulf Coast biogeographic region. The USGS, in cooperation with the National Park Service, is charged with designing and testing monitoring protocols for implementation at Cape Cod National Seashore. It is expected that many of the protocols will have direct application at other Seashore parks, as well as US Fish and Wildlife Service coastal refuges, within the biogeographic region.

The Long-term Coastal Ecosystem Monitoring Program at Cape Cod National Seashore is composed of numerous protocols that are relevant to the major ecosystem types (Estuaries and Salt Marshes, Barrier Islands/Spits/Dunes, Ponds and Freshwater Wetlands, Coastal Uplands). The meteorologic and atmospheric monitoring programs are integrally linked to all other monitoring protocols, as the atmosphere is critical to the cycling of elements, nutrients, and minerals through all of the Seashore's ecosystems. For example, information obtained from meteorologic and atmospheric monitoring may be relevant to interpreting both short- and long-term trends in water levels and water chemistry of ponds and freshwater wetlands.

## **EXECUTIVE SUMMARY**

Long-term monitoring of meteorologic and atmospheric variables (*e.g.*, precipitation, deposition, wind speed and direction) is fundamental to the Long-term Coastal Ecosystem Monitoring Program at Cape Cod National Seashore. Knowledge of trends in precipitation, storm frequency and intensity, deposition chemistry, and atmospheric ozone levels are essential to understanding and interpreting why changes in species composition, community structure, water and soil chemistry, or dynamic processes are occurring. This document identifies and briefly describes all of the meteorologic and atmospheric data that are currently being collected by the Seashore and cooperating agencies. Stations, each monitoring a different suite of parameters, are maintained throughout the Seashore in Provincetown, Truro, Wellfleet, South Wellfleet, and Eastham. Routine meteorologic data, including air temperature, wind speed and wind direction, precipitation, relative humidity, barometric pressure, and solar radiation are recorded. In addition, the Seashore is a National Atmospheric Deposition Program site, monitoring the major ions of wet precipitation; a Massachusetts Department of Environmental Protection Air Quality site, monitoring nitrogen oxides, ozone and volatile organic compounds; and an Interagency Monitoring of Protected Visual Environments site for visibility monitoring. Also, the Seashore maintains two fire-weather stations that collect data on 10-hour fuel moisture and relevant weather parameters.

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## INTRODUCTION

Meteorologic and atmospheric agents (*e.g.* wind, solar radiation, rain, fog, salt spray, deposition) are important factors governing the activity of organisms, community composition, and the cycling of materials through the ecosystems of Cape Cod National Seashore (Table 1). Storm surges and their associated winds and waves can alter ocean and estuarine shoreline configurations (Nordstrom 1992; Giese and Aubrey 1987; Zeigler *et al.* 1959), and dramatically affect estuarine circulation and sedimentation processes (Roman *et al.* 1997; Aubrey and Speer 1985). Drought periods or excess precipitation influence seasonal water balance, affecting wetlands, kettle ponds, vernal pools, and groundwater resources (Portnoy *et al.* 2001; Leblanc *et al.* 1986). The effects of atmospheric deposition include the acidification of lakes and streams, nutrient enrichment of coastal waters, depletion of soil nutrients leading to the decline of sensitive habitats, agricultural crop damage, and impacts on ecosystem diversity (Jaworski *et al.* 1997; Hinga *et al.* 1991). Godfrey *et al.* (1999) provide an excellent overview of relationships between meteorologic and atmospheric processes and ecosystem responses specific to the Seashore. The dynamic nature of the weather and its meteorologic and atmospheric agents demonstrate the need for an on-site, comprehensive, long-term monitoring program.

Cape Cod National Seashore has been monitoring some meteorologic and atmospheric-related parameters for 2-3 decades. Other parameters have been added to the program more recently and additional parameters are currently proposed. The purpose of this document is to identify the meteorologic and atmospheric data that are currently being collected by the Seashore and various cooperating agencies. A brief statement justifying why particular parameters are being monitored is included. Meteorologic and atmospheric data are essential to the understanding and interpretation of ecosystem trends that are detected from all aspects of the Long-term Ecosystem Monitoring Program. This document will be useful to researchers and resource management professionals interested in knowing the specific kinds of meteorologic and atmospheric data that are available at the Seashore. However, this document is not intended to analyze or synthesize the existing meteorologic and atmospheric data at the Seashore, nor is it intended to critique the existing monitoring efforts.

The first part of this document describes the overall meteorologic and atmospheric program at the Seashore and provides some general background information. The appendices provide overviews of the specific monitoring programs and lists published literature or websites where information about programs and protocols can be found.

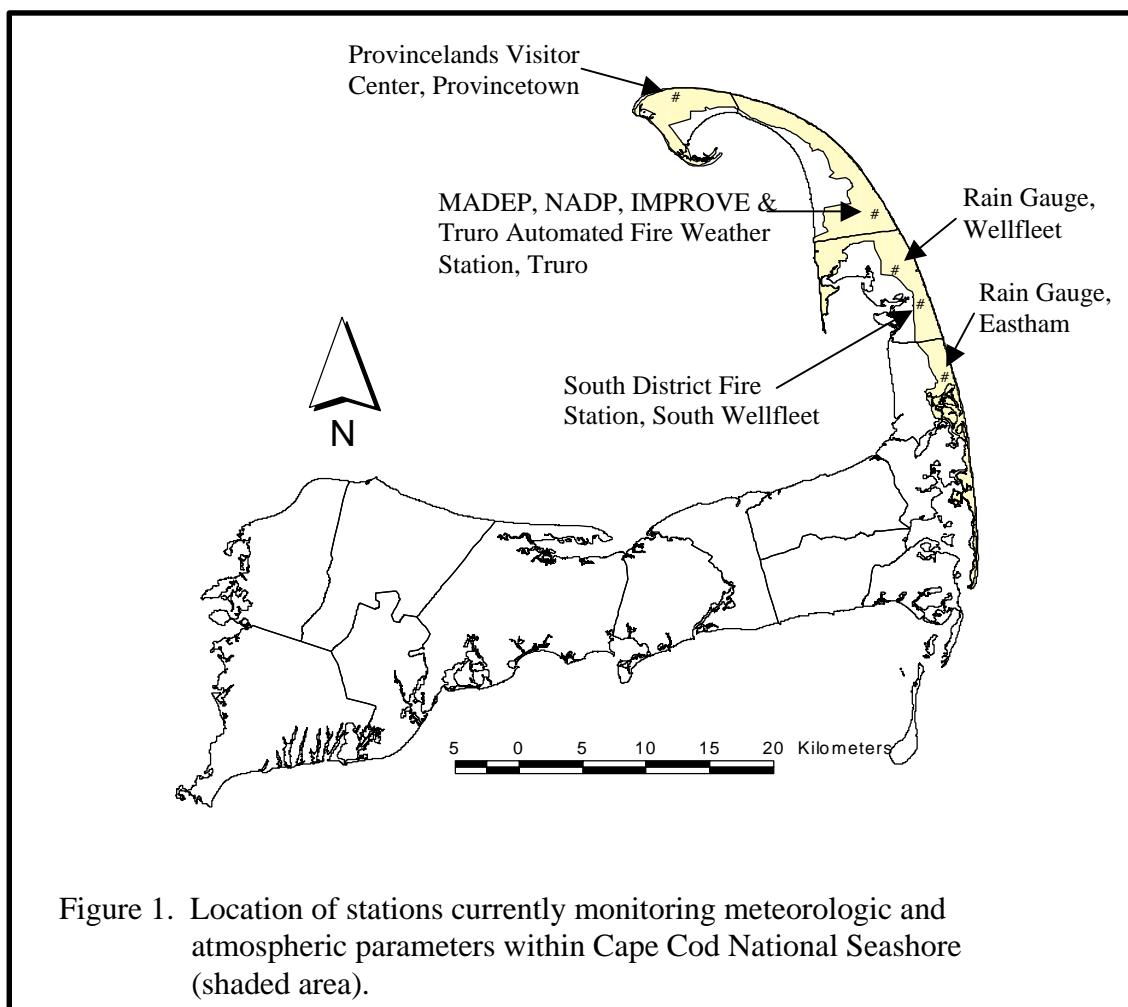


Table 1. A summary of relationships between meteorologic and atmospheric agents and the general ecosystem responses for each component of the coastal ecosystem.

<i>Ecosystem Components</i>	<i>Meteorologic and Atmospheric agents</i>	<i>Ecosystem responses</i>
Shoreline margins	Storm effects (winds and waves)	Shoreline and beach profile change
Barrier islands/spits/dune	Storm effects (winds and waves) Exposure gradients (wind and salt spray)	Physiographic change of habitat, community changes, soil enrichment/depletion
Estuaries	Storm effects, nutrient enrichments, atmospheric deposition	Sedimentation and circulation, eutrophication, productivity, community changes
Kettle ponds / freshwater habitats	Storm effects, atmospheric deposition, precipitation and drought	Water balance and turnover, acidification, toxicity, eutrophication, productivity, community changes
Upland vegetation (maritime forests and heathlands)	Exposure gradients (wind and salt spray), atmospheric deposition; precipitation and drought	Changes in community structure and productivity, soil enrichment/depletion, fire-management issues (fuel moisture)

## METEOROLOGIC MONITORING

Meteorologic information is currently monitored by several programs at five installations within the Seashore (Figure 1); Provincelands Visitor Center (PLVC) Weather Station, Air Quality Monitoring Network (Massachusetts Department of Environmental Protection - MADEP), National Atmospheric Deposition Program (NADP), Interagency Monitoring of Protected Visual Environments (IMPROVE), Truro Automated Fire Weather Station, South Wellfleet-South District Manual Fire Weather Station, and two satellite precipitation stations in Wellfleet and Eastham. Meteorologic parameters currently monitored at each station are presented in Table 2 and in Appendix I. Standard parameters that are measured are air temperature, wind speed / wind direction, precipitation amount and duration, relative humidity, barometric pressure, and solar radiation (not all parameters are recorded at each site). The fire-weather stations record many of the standard meteorologic parameters mentioned above during the fire season (March 15 through November 15), as well as dry/wet bulb (from which dew point can be calculated) and 10-hour fuel moisture (the amount of water in fuel expressed as a percentage of the oven-dry weight of the fuel). Fire-weather data



are used to predict the daily fire-danger index and can be entered into the Weather Information Management System (WIMS) for analysis of fire danger on a regional and national scale.

### AIR QUALITY AND ATMOSPHERIC DEPOSITION

The United States Environmental Protection Agency (USEPA) tracks national and regional ambient air quality trends. Ambient air quality data are used to verify compliance with air quality standards, to support development of regulations designed to reduce air pollution, to assess the effectiveness of existing air pollution control strategies, to provide aerometric data for long-term trend analysis and special research, and to fulfill USEPA reporting requirements for air quality data (MADEP 1998). Air quality and atmospheric deposition are currently monitored by three programs within Cape Cod National Seashore (Table 2). This section briefly describes these programs,

Table 2. Meteorologic and atmospheric parameters currently monitored at Cape Cod National Seashore.

<i>Parameter and Program</i>	<i>Daily frequency</i>	<i>Annual frequency</i>	<i>Length of Record</i>
<b>Meteorologic Parameters</b>			
Air temperature			
MADEP	Averaged hourly	Year round	1987 to present
PLVC	Real time, averaged hourly	April – November	1960's to present
SDFS	Once per 24hr,	March 15 – Nov 15	1964 to present
TAFWS	30 minute intervals	March - January	1980's to present
Wind speed/direction			
MADEP	Averaged hourly	Year round	1987 to present
PLVC	Real time averaged hourly	April – November	1960's to present
SDFS	Once per 24hr	March 15 – Nov 15	1964 to present
TAFWS	30 minute intervals	March - January	1980's to present
Wind chill			
PLVC	Real time, not archived	March 15 – Nov 15	No record
Precipitation amount & duration			
Eastham	Continuous chart recorder	Year round	1996 to present
PLVC	Continuous at pre-set intervals	April – November	1960's to present
NADP	Summarized weekly	Year round	1981 to present
SDFS	Once per 24hr (precipitation amount only)	March 15 –Nov 15	1964 to present
TAFWS	30 minute intervals	March - January	1980's to present
Wellfleet	Continuous chart recorder	Year round	1997 to present
Relative humidity			
MADEP	Averaged hourly	Year round	1987 to present
PLVC	Real time, averaged hourly	April – November	1960's to present
SDFS	Once per 24hr,	March 15 – Nov 15	1964 to present
TAFWS	30 minute intervals	March - January	1980's to present
Barometric pressure			
MADEP	Averaged hourly	Year round	1987 to present
PLVC	Real time, averaged hourly	April – November	1960's to present
Solar radiation			
MADEP	Averaged hourly	Year round	1987 to present
Dew point			
PLVC	Real time, averaged hourly	April – November	1960's to present
SDFS	Once per 24hr	March 15 – Nov 15	1964 to present
10-hour fuel moisture			
SDFS	Once per 24hr	March 15 – Nov 15	1964 to present
TAFWS	30 minute intervals	March - January	1980's to present

Table 2. continued.

<i>Parameter and Program</i>	<i>Daily frequency</i>	<i>Annual frequency</i>	<i>Length of Record</i>
<b>Atmospheric Parameters</b>			
Air Quality – NO, NO <sub>2</sub> , NO <sub>x</sub> , NO <sub>y</sub> , O <sub>3</sub>			
MADEP	Averaged hourly	Year round	1987 to present
Air Quality - VOC			
	8, 3hr canisters every 3 days	June, July, and August	
MADEP	24hr average taken every 6 <sup>th</sup> day	Year round	1987 to present
Wet deposition – K <sup>+</sup> , Na <sup>+</sup> , Ca <sup>+</sup> , Mg <sup>+</sup> , NO <sub>3</sub> <sup>-</sup> , Cl <sup>-</sup> , SO <sub>4</sub> <sup>2-</sup> , PO <sub>4</sub> <sup>3-</sup> , NH <sub>4</sub> <sup>+</sup> , H <sup>+</sup>			
NADP	Once per week	Year round	1981 to present
Particulate Matter – PM <sub>2.5</sub> , PM <sub>10</sub> and speciated particulate data			
IMPROVE	Every 3 days	Year round	2001 to present

Eastham: Rain gauge station, Young House, Nauset Road, Eastham  
 IMPROVE: Interagency Monitoring of Protected Visual Environments, Truro  
 MADEP: Massachusetts Department of Environmental Protection Air Quality Monitoring Network, Truro  
 NADP: National Atmospheric Deposition Program/ National Trends Network, Truro  
 PLVC: Provincelands Visitor Center Weather Station, Provincetown. The visitor center is closed during the winter months and as of this date no dedicated data line exists to transfer weather data year round from the station.  
 TASFWS: Truro Automated Fire Weather Station, Truro. Data are not collected during February when the station is offline for maintenance  
 SDFS: South District Manual Fire Weather Station, Wellfleet. Data at SDFS are collected only during fire season.  
 Wellfleet: Rain gauge station, north side of Duck Pond (Garrison property), Wellfleet

followed by a description of the specific air quality constituents that are monitored.

### Massachusetts Department of Environmental Protection Air Quality Monitoring Network

The MADEP Air Quality Monitoring Network oversees the collection of ambient air quality data within Massachusetts, including the station located in Truro. Seven criteria pollutants, for which national standards have been established, along with non-criteria pollutants and meteorologic data, are measured by the MADEP program (MADEP 1998). Only a few of these seven pollutants are monitored at Truro: nitrogen dioxide (NO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub> and NO<sub>y</sub>), nitric oxide (NO), and ozone (O<sub>3</sub>). In addition, Photochemical Assessment Monitoring Stations (PAMS) measure additional ozone precursor and reaction products such as volatile organic compounds (VOC).

## National Atmospheric Deposition Program

National Atmospheric Deposition Program (NADP) stations monitor wet atmospheric deposition, providing data where sensitive ecosystems are located as well as information on natural background levels of pollutants where urban influences are minimal. The NADP monitors and analyzes major ions in precipitation, including those affecting acidic rainfall and those that may have ecological effects. The NADP was initiated in the late 1970's, as a cooperative program among federal and state agencies, universities, electric utilities, and other industries to determine geographic patterns and trends in precipitation chemistry. The size of the NADP network grew rapidly in the 1980's and by the mid-1980's the NADP had grown to nearly 200 sites and became known as the NADP/NTN (National Atmospheric Deposition Program / National Trends Network) and is coordinated from the Program Office at Illinois State Water Survey in Champaign-Urbana, IL. Currently there are 220 sites nationwide with thirty-three National Park Service units included in this network, twenty-five of which are supported by the National Park Service-Air Resources Division. The NADP program at the Seashore was established in December 1981.

As a brief background, atmospheric deposition occurs when chemical compounds fall to earth in either dry (gas or particles) or wet form (rain, fog, or snow). These pollutants can be transported over long distances by weather patterns and deposited hundreds of kilometers from their original sources. The effects of atmospheric deposition include the acidification and eutrophication of lakes, streams, and coastal waters, soil nutrient depletion, the decline of sensitive forest ecosystems, and impact on ecosystem biodiversity (USEPA 2000b; Jaworski *et al.* 1997; Hinga *et al.* 1991). Atmospheric deposition of mercury has been implicated as the major source of mercury in the kettle ponds of the Seashore (Godfrey *et al.* 1999).

Total atmospheric deposition consists of wet deposition, commonly known as "acid rain", and dry deposition. Wet deposition is the portion of material dissolved in cloud droplets that is deposited during precipitation events. Dry deposition is the portion of material deposited during periods of no precipitation as particles or in a gaseous form. Dry deposition can account for 20-60 percent of the total atmospheric deposition (USEPA 2000b). Monitoring wet and dry deposition typically includes the measurement of key chemical components (such as hydrogen, potassium, sodium, calcium, magnesium, nitrate, chloride, sulfate, and phosphate ions) as well as precipitation amounts. Analyses of dry deposition must also include meteorologic measurements that are used to estimate the rate of actual deposition or "flux" (USEPA 2000b).

## Interagency Monitoring of Protected Visual Environments

Federal land managers are required by the 1977 Clean Air Act to protect visibility at designated Federal Class I visibility areas (most National Parks and designated Wilderness Areas and many National Monuments) from pollution. The Interagency

Monitoring of Protected Visual Environments (IMPROVE), a particulate monitoring program that was established in 1987, is a collaborative effort between federal land managers (National Park Service, US Forest Service, US Fish and Wildlife Service, Bureau of Land Management, and the US Environmental Protection Agency) and cooperating agencies to monitor visibility and particulate components in these protected areas. Although not currently a Federal Class I visibility area, IMPROVE sampling at the Seashore was initiated in April of 2001.

The IMPROVE program is designed to establish current background aerosol concentrations; to identify chemical constituents and emission sources for existing human-made visibility impairment; to document long-term trends; and to provide regional haze monitoring (Crocker Nuclear Laboratory 1999). The program monitors the composition of air-borne fine particles,  $PM_{2.5}$  (particles less than 2.5 micrometers), and larger particles,  $PM_{10}$  (particles equal to or less than 10 micrometers). Between 1996 and 1999 there were approximately 80 monitoring sites throughout the US. In 2000 the number of sites increased to approximately 145 sites, 110 are under the direct control of the IMPROVE Steering committee. The remaining 35 sites are referred to as "Protocol" sites and are under the direction of one of the cooperating agencies (Crocker Nuclear Laboratory, 2000). Protocol sites are primarily in remote areas and the operation of these sites are identical to that of IMPROVE sites. The monitoring site at Cape Cod National Seashore is a protocol site.

### **Description of Pollutants Monitored in Air Quality and Atmospheric Deposition Programs**

The following provides a brief description of the pollutants that are included in the MADEP, NADP, and IMPROVE programs at the Seashore.

#### Nitrogen oxides ( $NO_x$ and $NO_y$ )

Nitrogen oxides ( $NO_x$ ) is the term used to describe the sum of NO and  $NO_2$ .  $NO_y$  is the term used to describe the sum of all oxidized nitrogen species (*i.e.* NO,  $NO_2$ ,  $NO_3$ ,  $HNO_3$ ,  $N_2H_5$ , alkyl nitrates, and peroxyacetyl nitrates or PAN). Nitrogen dioxide ( $NO_2$ ) is a highly reactive gas formed in ambient air through the oxidation of nitric oxide (NO). Anthropogenic emission of  $NO_x$  and  $NO_y$  compounds account for a large proportion of all nitrogen input to the environment, with the major sources originating from high-temperature combustion processes such as those occurring in automobiles and power plants (USEPA 2000b). Natural sources of nitrogen oxides are lightening, biotic and abiotic processes in the soil, and stratosphere intrusion. Nitrogen oxides have a wide range of influences from public health (adverse respiratory effects) to the environment, including eutrophication of water bodies, global warming, and stratospheric ozone depletion (USEPA 2000b). Nitrogen oxides also react in the atmosphere to form ozone, acid precipitation, and particulate matter. Of most relevance to the Seashore, atmospheric deposition of nitrogen is known to be a major cause of

nutrient enrichment in estuaries of the northeastern US (Jaworski *et al.* 1997). This nutrient loading can lead to changes in community composition and structure. Annual mean trends data indicate that NO<sub>2</sub> was 14% lower in 1998 than in 1989. In the past 10 ten years, NO<sub>2</sub> concentration has decreased 13% in the New England region (USEPA 2000b).

### Ozone (O<sub>3</sub>)

There are two types of ozone, stratospheric ozone which is beneficial and ground level ozone which is a health and environmental problem. Ozone is naturally occurring in the earth's stratosphere and provides a protective layer by absorbing a portion of the sun's harmful radiation (ultraviolet radiation) and preventing it from reaching the earth's surface. Ultraviolet radiation has been linked to a variety of health and environmental problems, such as skin cancer, and cataracts, and may harm agricultural crops and some forms of marine life.

Major contributing factors to stratospheric ozone depletion are chlorofluorocarbons, halons, and other organic compounds that contain chlorine or bromine. Chlorofluorocarbons were used extensively as refrigerants and solvents, but were banned in the US in the 1970's. One chlorine atom can destroy over 100,000 ozone molecules, and thus, can deplete ozone faster than it is naturally created, resulting in long-term ozone depletion (USEPA 1999). One example of ozone depletion is the annual ozone "hole" that has occurred during the Antarctic spring since the early 1980's. The ozone hole is a large area of the stratosphere with extremely low amounts of ozone. Ozone depletion also occurs at other latitudes, for example, in the US stratospheric ozone levels have fallen 5-10% depending on the season.

Ground level ozone is a pervasive pollution problem in the US and is the major component of smog (USEPA 2000b). Ground-level ozone is formed readily in the atmosphere by the reaction of volatile organic compounds and nitrogen oxides, in the presence of heat and sunlight. Weather patterns can transport ozone and its associated precursor pollutants hundreds of kilometers from their upwind sources. The highest ambient ozone concentrations are typically found at suburban sites, resulting from the downwind transport of pollutants from urban centers (USEPA 2000a). Ambient ozone concentrations are also influenced by biomass burning, such as wildfires, which can have a large scale regional influence on ozone levels.

Short-term (1-3 hours) and long-term (6-8 hours) exposures to ambient ozone concentrations have been linked to a variety of respiratory disorders (USEPA 2000b). The environmental effects of ozone range from reductions in agriculture and commercial forest yields, reduced survival of sensitive tree seedlings, damage to foliage, and increased susceptibility to disease, pests and other environmental stresses, such as harsh weather (USEPA 2000b). Long-term effects of elevated ground level ozone may result in the disappearance of sensitive species, as they are out-competed by more resistant species, thereby altering habitat quality, structure, and function.

Nationally, peak 1-hour O<sub>3</sub> concentrations have declined 4% over the past ten years and 17% over the past 20 years (USEPA 2000b). Regionally, New England has experienced a similar decrease (9%), however the Mid-Atlantic, Southeast, Central, and Northwest regions have shown an increase in O<sub>3</sub> concentrations (USEPA 2000b). Ten-year trend data are available for 24 National Park Service sites that monitor 8-hour ozone concentrations, including Cape Cod National Seashore. These sites are a special subset of rural environments (all National Parks and Wilderness Areas exceeding 2,000 hectares) and are accorded a higher degree of protection under the Clean Air Act. From 1989 to 1998 the composite mean of ozone concentration remained the same in these areas (USEPA 2000b).

### Particulate matter (PM)

Particulate matter is the general term used for a mixture of solid and liquid droplets found in air. These particles vary in shape and size and are produced from a variety of anthropogenic and natural sources. Particulate matter is divided into two types, coarse and fine particles. Coarse particles range in size from 2.5 to 10 micrometers, and are formed from sources such as road dust, construction, agriculture, and sea spray. Fine particles are less than 2.5 micrometers and are created from the smoke of residential wood burning, wildfires and prescribed burns, exhaust from motor vehicles, power plants, incinerators, refineries, and similar sources. Particles emitted directly from a source are called primary particles. These particles undergo few changes between the source and later deposition. Secondary particles are formed in the atmosphere by gases (*i.e.* sulfur dioxide and nitrogen dioxides) originating from the sources previously mentioned. The most common secondary particles are sulfates and nitrates that can fall to earth either as dry deposition or as wet deposition in the form of acid precipitation (USEPA 1994). As a result, the chemical and physical composition of particulate matter can vary depending on location, time of year, and meteorology (USEPA 2000b).

The original standards for PM, established in 1971, were for total suspended particulate matter (TSP). In 1987, EPA replaced TSP standards with PM<sub>10</sub> standards (particles equal to or less than 10 micrometers) to focus on these smaller particles that cause a greater health concern because of their ability to penetrate sensitive regions of the respiratory tract (USEPA 2000b). Adverse health affects include aggravation of respiratory conditions such as asthma, decreased lung function, and increased respiratory symptoms and disease. Particulate matter also has environmental impacts. Fine particulate matter (particles less than 2.5 micrometers), PM<sub>2.5</sub>, is the major cause of reduced visibility in parts of the US. Sulfate and organic carbon, from motor vehicles and industrial processes, comprise the majority of PM<sub>2.5</sub> concentrations (USEPA 2000a). Deposition of particles containing nitrogen and sulfur onto land or water bodies may change acidity and nutrient balance, influencing community structure, species composition, and buffering capacities. Particles that are deposited directly onto plant leaves can, depending on their chemical composition, corrode leaf surfaces or interfere with plant metabolism.



Annual mean  $PM_{10}$  concentrations have decreased 25% across the country over the ten year period from 1989 to 1998. Higher annual mean concentrations were typically observed at the eastern US sites compared to western locations. This is mainly due to the higher sulfate concentrations in the East (EPA 2000a, b). In the New England region,  $PM_{10}$  concentrations have decreased 19% between 1989-1998. Fine particulate ( $PM_{2.5}$ ) concentrations have increased at 7 of 10 rural eastern sites, while during this same time period average  $PM_{2.5}$  levels in the western US decreased 5% (USEPA 2000b).

### Volatile Organic Compounds (VOCs)

Volatile organic compounds contain organic chemicals that evaporate easily. There are many types of volatile organic compounds and they are emitted from a variety of sources. Fossil fuel deposits, volcanoes, vegetation, and bacteria are natural sources of VOCs. Some trees also emit VOCs, such as isoprene and monoterpenes (USEPA 2000b). Anthropogenic sources include motor vehicles, chemical plants, refineries, factories, consumer and commercial products, and the evaporation of gasoline (from fueling stations), oil-based paints, and cleaning solvents. In the presence of sunlight and heat, VOC's react with nitrogen oxides to form ground-level ozone, a serious environmental problem in the US. National emission trends for VOCs from anthropogenic sources have decreased 20% from 1989 to 1998 (USEPA 2000b).

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## **APPENDIX I**

A description of existing air quality and meteorologic data collection programs within Cape Cod National Seashore.

- Cape Cod National Seashore Rain Gauge Stations
- Interagency Monitoring of Protected Environments (IMPROVE)
- Massachusetts Department of Environmental Protection (MADEP), Air Quality Monitoring Network
- National Atmospheric Deposition Program / National Trends Network (NADP/NTN).
- Provincelands Visitor Center Remote Weather Station, Provincetown, MA
- South District Manual Fire Weather Station, South Wellfleet, MA
- Truro Automated Fire-Weather Monitoring Station, Truro, MA

### **Cape Cod National Seashore Rain Gauge Stations**

The Cape Cod National Seashore maintains two rain gauges within Seashore boundaries, one each in Wellfleet and Eastham, MA.

Site and Operator: Staff from the North Atlantic Coastal Laboratory at Cape Cod National Seashore maintain and archive precipitation data (amount and duration) collected from two rain gauges located in Wellfleet and Eastham. The Wellfleet station is located on the north side of Duck Pond (on the Garrison property within the Seashore boundary) (LAT: +41° 56' 03.0"; LONG -69° 59' 58.2"). The Eastham station is located behind the Young House (a Seashore owned property) off of Nauset Road (LAT: +41° 50' 52.7"; LONG -69° 57' 22.2")

Contact: Cape Cod National Seashore  
99 Marconi Site Road  
Wellfleet, MA 02667  
(508) 487-3262 (North Atlantic Coastal Laboratory)  
(508) 349-3785 (Headquarters)

Sample Collection and Analysis: The rain gauges collect continuous data on precipitation via chart recorder.

Quality Assurance and Quality Control: Data records are maintained by Cape Cod National Seashore and as of this writing no standardized quality assurance and quality control are in effect.

Data Management and Reports: Charts are collected weekly (on Tuesdays) and daily precipitation values are stored in a spreadsheet. Data are archived at the North Atlantic Coastal Laboratory at Cape Cod National Seashore. The data record from the Eastham site extends from 1996 to present and the data record from the Wellfleet site extends from 1997 to present.

## **Interagency Monitoring of Protected Visual Environments (IMPROVE)**

Interagency Monitoring of Protected Visual Environments (IMPROVE) is a collaborative effort between federal land managers and inter-state agencies to monitor the composition of airborne particles affecting visibility. Air quality data are collected and submitted into the Aerometric Information Retrieval System (AIRS), a computer-based repository of national air quality information that is administered by the US Environmental Protection Agency (USEPA).

Site and Operator: The IMPROVE sampler located at Cape Cod National Seashore is part of the USEPA approved MADEP PM<sub>2.5</sub> monitoring network. The use of the IMPROVE sampler as part of the PM<sub>2.5</sub> network is authorized in 40 CFR Part 5B, Appendix C. The MADEP purchased the IMPROVE sampler and is responsible for its maintenance (*i.e.* repairs, calibration, supplies) and for the cost of all filter analysis conducted by the Crocker Nuclear Laboratory at University of California, Davis, CA (UC Davis). The sampler is located in a shelter installed at the Fox Bottom area in Truro, MA. The station is located on Warehouse Road (off Kings' Highway) in Truro (LAT: +41° 58' 33"; LONG -70° 01' 29"; 41m elevation) and has been operational since April 2001.

Contact: Cape Cod National Seashore  
99 Marconi Site Road  
Wellfleet, MA 02667  
(508) 349-3785 (Headquarters)

Sample Collection and Analysis: Samples are collected and processed as detailed in the Standard Operating Procedures for the IMPROVE monitoring program (Crocker National Laboratory 2000; 1999). All IMPROVE sites collect samples three times per week year round. PM<sub>2.5</sub> (fine) particles are collected on Teflon, nylon, and quartz filters and PM<sub>10</sub> particles on a Teflon filter. PM<sub>2.5</sub> particles are analyzed for the particle mass, optical absorption, major and trace elements, organic and elemental carbon, and nitrate. PM<sub>10</sub> particles are measure for mass. Personnel from Cape Cod National Seashore collect the exposed samples, set the instrument for the next scheduled sample run date, and ship the collected, exposed samples to the Crocker Nuclear Laboratory at U.C. Davis for analyses.

Quality Assurance and Quality Control: All data collected from the IMPROVE sites within National Park Service units are validated by the National Park Service Monitoring support contractors, currently Air Resource Specialists (ARS) and UC Davis, and submitted to the USEPA's AIRS database.

Data Management and Reports: The primary optical and scene monitoring contractor is Air Resource Specialists, Inc. (ARS). The primary aerosol monitoring contractor is the Crocker Nuclear Laboratory at U.C. Davis. Seasonal and annual data reports, special study data reports, technical publications, and other data and analysis reports are prepared by these contractors. Digital data bases are maintained by the contractors and

distributed to sponsoring agencies. The titles and availability of reports and digital data are noted in IMPROVE Newsletters and are available at the following website: <http://www2.nature.nps.gov/ard/impr/>.

## **Massachusetts Department of Environmental Protection (MADEP)**

### **Air Quality Monitoring Network**

The Air Assessment Branch (AAB) of the Massachusetts Department of Environmental Protection (MADEP) operates an ambient air monitoring network of 42 sites located in 27 cities and towns throughout Massachusetts. AAB also oversees an industrial network of six stations located in two cities and one town. Air quality data are collected and submitted into the Aerometric Information Retrieval System (AIRS), a computer-based repository of national air quality information that is administered by the US Environmental Protection Agency (USEPA). The ambient air quality data are used for federal and state regulatory compliance and monitoring, and to provide aerometric data for research.

Site and Operator: The Air Assessment Branch has operated an air quality monitoring station (site no. 23; AIRS code 25-001-0002) at the Fox Bottom area in Truro, MA since 1987. The station is located on Warehouse Road (off Kings' Highway) in Truro (LAT: +41° 58' 33"; LONG -70° 01' 29"; 41m elevation).

Contact: Jerry Sheehan (978) 682-4557  
Massachusetts Department of Environmental Protection  
Air Assessment Branch  
Wall Experiment Station  
37 Shattuck Street  
Lawrence, MA 01843

Sample Collection and Analysis: Air quality parameters monitored at this station are nitrogen dioxide (NO<sub>2</sub>), nitric oxide (NO), nitrogen oxides (NO<sub>x</sub> and NO<sub>y</sub>), ozone (O<sub>3</sub>), PM<sub>2.5</sub>, PM<sub>10</sub>, and ozone precursors and reaction products including volatile organic compounds (VOC). NO<sub>x</sub>, NO<sub>y</sub>, and NO are not criteria pollutants and PM<sub>2.5</sub> and PM<sub>10</sub> are measured using non-referenced methods (*i.e.* IMPROVE sampler). Currently the air quality parameters CO, SO<sub>2</sub>, and Pb are not monitored by the MADEP site in Truro (MADEP 1998). The closest locations monitoring these parameters are Boston (CO, Pb) and Fall River (SO<sub>2</sub>) (MADEP 1998).

The station is housed in a 20 ft. by 8 ft. freestanding trailer. Continuous measurements of air quality parameters are recorded via paperless DAS system. Meteorologic instrumentation is interfaced with a data translator mounted on a telescopic, 10m tower that continuously record wind speed and direction, relative humidity, barometric pressure, and temperature. Total solar radiation is also continuously recorded with a pyranometer mounted on the corner of the roof. Ambient air is actively collected at a height of 5m through a glass manifold equipped with sampling ports and fitted with a squirrel cage fan. Intermittent monitors measure VOC using eight, 3-hour VOC canisters collected every 3 days during the months of June, July, and August. During the remainder of the year a 24-hour sample is collected every 6<sup>th</sup> day. VOC are collected through a stainless steel tube into stainless steel canisters fitted with 16 valve sampling sequencer set for consecutive, three hour samples. These samples are



analyzed using an automated gas chromatograph at the Wall Experimental Station, Lawrence, MA. All instrumentation used to monitor air quality parameters are either EPA referenced methods or equivalent instrumentation.

Quality Assurance and Quality Control: The MADEP verifies all data during a 45 day quality assurance and quality control period after which the data are available.

Data Management and Reports: Digital data are received by a 16 channel data logger and managed by data acquisition / communication software. Data compilations are performed using database management software. The data from the continuous monitors are averaged to provide hourly concentrations (interruptions of digital data input that exceed thirty minutes are flagged as unreliable data points). The data record extends from 1987 to present.

Data are available after a 45 day quality control and quality assurance period by download with permission from the MADEP, Air Assessment Branch. Annual reports are also available via the Internet ( <http://www.state.ma.us/dep/bwp/daqc/> ) or copies can be requested by contacting John Lane at 978-975-1138 x 304 or via e-mail at [John.Lane@state.ma.us](mailto:John.Lane@state.ma.us). Information is also available through AIRS, a repository for pollution data.

### **National Atmospheric Deposition Program / National Trends Network**

The National Park Service participates in the National Atmospheric Deposition Program / National Trends Network (NADP/NTN). This network provides long-term geographical and temporal trends data on atmospheric depositional chemistry. The National Park Service funds 25 stations within this network.

Site and Operator: Cape Cod National Seashore has sponsored an NADP site (site no. 220155, code MA01), operated by the North Atlantic Coastal Laboratory since December 1981. The site is located on Warehouse Road (off of King' Highway), Truro, MA. (LAT: +41° 58' 32"; LONG -70° 01' 29"; 41m elevation).

Contact: Cape Cod National Seashore  
99 Marconi Site Road  
Wellfleet, MA 02667  
(508) 349-3785 (Headquarters)

NADP Program Office Coordinator  
Scott Dossett, (217) 244-0372  
[sdossett@uiuc.edu](mailto:sdossett@uiuc.edu)

Sample Collection and Analysis: Precipitation data are collected weekly on precipitation amounts and precipitation chemistry. Precipitation samples are collected by Seashore staff each Tuesday morning in a wet/dry sampler fitted with a 13 liter polyethylene collection bucket. Samples are transferred from the collection bucket to a shipping bottle. The sample is sent to the Central Analytical Laboratory (CAL) at the Illinois State Water Survey in Champaign-Urbana, IL, for analyses. The following parameters are measured:  $K^+$  (potassium),  $Na^+$  (sodium),  $Ca^{2+}$  (calcium), and  $Mg^{2+}$  (magnesium) using atomic absorption spectroscopy;  $NO_3^-$  (nitrate),  $Cl^-$  (chloride),  $SO_4^{2-}$  (sulfate),  $PO_4^{3-}$  (phosphate) using ion chromatography;  $NH_4^+$  (ammonium) using automated colorimetry; and  $H^+$  (pH) using ion specific electrode. Precipitation amounts in the field are recorded on a continuous stripchart using a rain gauge. Standardized protocols are available from the NADP and copies of protocols are located at the North Atlantic Coastal Laboratory. If there is sufficient sample, on-site measurements of pH and conductivity are made at the North Atlantic Laboratory using a digital pH meter.

Quality Assurance and Quality Control: All data collected from the NADP sites within National Park Service units are validated by the National Park Service Monitoring support contractor, currently Air Resource Specialists (ARS), and submitted to the USEPA's AIRS database.

Data Management and Reports: All data are processed by staff at the National Atmospheric Deposition Program located at the Illinois State Water Survey,

Champaign-Urbana, IL. Summary accounts of data are produced (hardcopy, diskettes, tapes, or website <http://nadp.sws.uiuc.edu>) and are available for annual, quarterly, monthly, weekly and daily periods. National isopleth maps of precipitation amounts and the concentration of depositional ions in precipitation are published annually. The data record extends from 1981 to present.

### **Provincelands Visitor Center Remote Weather Station**

Weather parameters have been manually recorded at Provincelands Visitor Center (PLVC) since the 1960's. An automated weather station was installed at PLVC in October 1997. The hardware and software were updated in the spring and fall of 2000, respectively. It is used as an educational and interpretive tool by National Park Service staff at the Visitor Center.

Site and Operator: The weather station is located at the PLVC (LAT: +42° 04' 40"; LONG -70° 11' 45"; 29m elevation). The equipment is operated by staff at the Visitor Center and serviced by contract. The Visitor Center is located on Race Point Road (off of Route 6) in Provincetown and is open from 9am to 5pm daily, mid-April through late-November. Currently, weather data are only collected from April through November when the visitor is open to the public and manned by Seashore staff. However, the recent upgrades in hardware and software will allow data to be collected year-round if a dedicated phone line is installed for this purpose.

Contact: Cape Cod National Seashore  
99 Marconi Site Road  
Wellfleet, MA 02667  
Provincelands Visitor Center: (508) 487-1256 (Nov 15 - March15)  
(508) 349-3785 (Headquarters)

Sample Collection and Analysis: The weather station is a wireless sensor assembly that records data at pre-set intervals on wind speed and wind direction, wind chill, air temperature, barometric pressure, humidity, dew point, and precipitation amount. Daily minimum and maximums are also recorded for each of these parameters. Data are downloaded and stored on a computer and real time and archived data are available via a computer located in the Visitor Center.

Quality Assurance and Quality Control: Data records are maintained by Cape Cod National Seashore and as of this writing no standardized quality assurance and quality control are in effect.

Data Management and Reports: Data that are downloaded from the weather station are displayed real time and can be accessed from the computer at the Provincelands Visitor Center. Staff at the Visitor Center currently produce written monthly reports, however in the future reports will be generated automatically from the software. The recent upgrades allow the weather station to collect data year-round and to transmit electronic data to other sources (*e.g.* a website), however a dedicated phone line must be installed for this to occur. The data record dates from the 1960's to present, but is incomplete for some years.

### **South District Manual Fire Weather Station**

The South District Manual Fire Weather Station is part of the fire management program at the Seashore. The station collects data that are used, along with other resources (*e.g.* National Fire Danger Rating System (NFDRS) website), to predict and help suppress wild fires and to plan prescribed burn activities within the Seashore.

Site and Operator: The weather station is located 75m SW of the South District Fire Cache in South Wellfleet, MA (LAT: +41° 54' 20"; LONG -69° 58' 53"). The site is operated by Cape Cod National Seashore Fire Management staff and is part of the Weather Information Management System (WIMS), station no. 191202; however, due to personnel and computer constraints the data are not currently entered into the WIMS system (see description of WIMS at end of this section).

Contact: Fire Management Officer  
Cape Cod National Seashore  
99 Marconi Site Road  
Wellfleet, MA 02667  
(508) 349-3785 (Headquarters)

Sample Collection and Analysis: The South District Manual Fire Weather Station collects daily data on dry bulb/wet bulb (dew point) by standard electric fan psychrometer, wind speed and wind direction (3-cup anemometer and wind vane), 24-hr precipitation amount, and 10-hr fuel moisture (the measured moisture content of the 1/2- inch fuel moisture sticks to the nearest gram) by total weight fuel stick method. Air temperature, relative humidity, 24-hr minimum and maximum for temperature and humidity are recorded by a hydrothermograph (precision to approximately 4 hours). Data are collected daily during the fire season, March 15 through November 15, and are manually annotated and entered into a log book. The Fire Management staff at the Seashore maintain the instruments and data records.

Quality Assurance and Quality Control: Data records are maintained by Cape Cod National Seashore and as of this writing no standardized quality assurance and quality control are in effect.

Data Management and Reports: The Seashore Fire Management staff log data from the fire-weather station. Summaries of data are available by request from the Fire Management personnel at the Seashore. The data record extends from 1964 to present, however incomplete data occur for some years.

Weather Information Management System (WIMS): WIMS is a comprehensive system designed to manage forestry weather information nationwide and is used for maintaining fire weather observation catalogs, indexing, and forecast purposes. It accommodates the weather information needs of users throughout the National Park Service, National Forest Service, and other forestry and management agencies, providing timely access to many sources of forestry weather data and related weather

information. WIMS is used for maintaining fire-weather observation catalogs, indexing, and forecasting purposes. WIMS is the host site for the National Fire Danger Rating System (NFDRS). The NFDRS, which became operational in 1972, is a set of computer programs that allow land management agencies to estimate and forecast daily fire danger for a given location. Fire danger ratings are guides for initiating suppression activities and selecting the appropriate level of response to a reported wildfire in lieu of detailed, site- and time-specific information (NFDRS website: <http://www.seawfo.noaa.gov/fire/olm/nfdrs.htm>). The primary support personnel for WIMS are the US Forest Service, National Information Systems Team Support Group in Boise, Idaho, at the National Interagency Fire Center. One way of accessing WIMS data is through the Internet using DOINet, however access is restricted and one must have a log-on ID.

### **Truro Automated Fire-Weather Monitoring Station Fire**

The fire-weather monitoring station, located in Truro, MA, is a remote, fire-weather collection device. The fire weather data are used along with other sources, (*e.g.* National Fire Danger Rating System (NFDRS) website), by fire management programs in fire suppression, prescribed burn planning and execution, and development of long-range fire management plans.

Site and Operator: The station is located within Cape Cod National Seashore on Warehouse Road (off of King' Highway), Truro, MA. (LAT: +41° 58' 30"; LONG -70° 01' 31"; 41m elevation). The site is operated by Cape Cod National Seashore Fire Management staff and is part of the Weather Information Management System (WIMS), station no. 191203; however, due to personnel and computer constraints the data are not currently entered into the WIMS system.

Contact: Fire Management Officer  
Cape Cod National Seashore  
99 Marconi Site Road  
Wellfleet, MA 02667  
(508) 349-3785 (Headquarters)

Sample Collection and Analysis: The automated fire-weather station collects continuous data on wind speed and direction, air temperature, relative humidity, precipitation amount, and 10-hour fuel moisture. An additional port is available for the collection of total solar radiation; however this information is not currently not collected. Data are collected by a data logger and are downloaded to a computer. Data are automatically updated every thirty minutes, 24 hours a day, 11 months of the year. The remote station is shut down annually, for one month (usually February), for maintenance.

Quality Assurance and Quality Control: Data records are maintained by Cape Cod National Seashore and as of this writing no standardized quality assurance and quality control are in effect.

Data Management and Reports: Reports are not currently generated for this data, however summaries of data are available by request from the Fire Management personnel at the Seashore. The data record extends from 1980's to present, however incomplete data occurs for some years.

## APPENDIX II

## Related Websites

Agency	Website	Description
CAPITA	<a href="http://capita.wustl.edu/">http://capita.wustl.edu/</a>	Center for Air Pollution Impact and Trend Analysis; air pollution data and links to air quality related websites
IMPROVE	<a href="http://www2.nature.nps.gov/ard/vis/sop/index.html">http://www2.nature.nps.gov/ard/vis/sop/index.html</a>	National Park Service website describing the IMPROVE program and standard operating procedures
MADEP	<a href="http://www.magnet.state.ma.us/dep/dephome.htm">http://www.magnet.state.ma.us/dep/dephome.htm</a>	Home page for MADEP links to MADEP programs, regions, and publications.
MADEP, Air Program Planning Unit	<a href="http://www.state.ma.us/dep/bwp/daqc/">http://www.state.ma.us/dep/bwp/daqc/</a>	Home page for MADEP, Air Program Planning Unit. Links to ozone forecasts, publications, and regulations
NADP/NTN	<a href="http://nadp.sws.uiuc.edu/">http://nadp.sws.uiuc.edu/</a>	National Atmospheric Deposition Program/National Trends Network (NAD/NTN) homepage. Maps and data nationwide precipitation monitoring network.
NADP/NTN -MA01	<a href="http://nadp.sws.uiuc.edu/nadpdata/siteinfo.asp?id=MA01&amp;net=NADP">http://nadp.sws.uiuc.edu/nadpdata/siteinfo.asp?id=MA01&amp;net=NADP</a>	NADP/NTN Monitoring Location MA01- North Atlantic Coastal Laboratory, Truro, MA
USEPA	<a href="http://www.epa.gov">http://www.epa.gov</a>	Home page for USEPA
USEPA - AIRS	<a href="http://www.epa.gov/airs/">http://www.epa.gov/airs/</a>	Aerometric Information Retrieval System (AIRS) homepage. The world's largest air pollution database. Links to monitoring statistics, maps, and database products.
USEPA - CEIS	<a href="http://www.epa.gov/eq/">http://www.epa.gov/eq/</a>	Center for Environmental Information and Statistics (CEIS). Information on environmental quality, status, and trends.
USEPA publications	<a href="http://www.epa.gov/epahome/publications.htm">http://www.epa.gov/epahome/publications.htm</a>	USEPA publication sources. Links to the National Service Center for Environmental Publications (NSCEP) and National Environmental Publications Internet Site (NEPIS)
NPS	<a href="http://www.nifc.nps.gov/index.htm">http://www.nifc.nps.gov/index.htm</a>	Fire Management Program Center (FMPC) of the National Park Service
NFDRS	<a href="http://www.seawfo.noaa.gov/fire/olm/nfdrs.htm">http://www.seawfo.noaa.gov/fire/olm/nfdrs.htm</a>	National Fire Danger Rating System homepage
WIMS	<a href="http://www.fire.nps.gov/fire/policy/rm18/chap16.htm">http://www.fire.nps.gov/fire/policy/rm18/chap16.htm</a>	Weather Information Management System support and access information